ANNUAL REPORT

January 1, 1989 - December 31, 1989

to

THE OFFICE OF NAVAL RESEARCH

Grant Number: N00014-89-J-1364

Grant Title:

Theoretical and Modeling Studies of The Marine Planetary Boundary Layer

Principal Investigator: David A. Randall

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Research Abstract

GOALS: To gain an improved theoretical understanding of and predictive capability for partly cloudy boundary layers, and to test these ideas against data acquired in the field. Also, to investigate the role of air-sea interactions in regulating cloud amount in the marine boundary layer.

OBJECTIVES: To produce an extensive set of theoretical and numerical results,

APPROACH: We have developed a new type of boundary-layer model that combines second-order closure with a bulk representation of the vertical structure. The boundary-layer depth and turbulence kinetic energy (TKE) are prognostically determined. The large turbulent eddies that are primarily responsible for the fluxes are modeled as convective circulations, with ascending and descending branches. The upper part of the attached figure illustrates the structure of the PBL as represented in the model. The interior of the boundary layer is bounded above by a thin entrainment layer and below by a thin ventilation layer. Conservative variables such as the equivalent potential temperature have quadratic profiles in the interior. Convective circulations occur, with rising branches occupying fractional area σ, which is predicted by the model. The lower panel is a plot of the fractional area covered by rising motion, σ, as a function of the ratio of the entrainment rate to the ventilation rate. As indicated in the figure, the model predicts that as the entrainment rate increases the fractional area covered by rising motion decreases; rapid entrainment is associated with small σ.

TASKS COMPLETED: The new theoretical model has been developed and used to derive the scientific results mentioned below. The same model is being tested as a numerical prediction tool.

RESULTS: The model makes a number of new predictions concerning the convective turbulence of cloudy layers. For the special case of a well-mixed layer, it predicts that the fractional area

covered by rising motion is near 1/2, and that dissipation in the interior of the layer is weak. When the dissipation is weak and the fractional area covered by rising motion is small, the model gives the "compensating subsidence -- detrainment" relationship that has become familiar in cumulus parameterization theories. When the dissipation is strong and the fractional area covered by rising motion is near 1/2, the model gives downgradient diffusion. For the shallow cumulus regime, the model predicts that the fractional area covered by rising motion is smaller for the case of large-scale rising motion than for large-scale sinking motion. These model predictions are consistent with a variety of observed balances in convective layers.

ACCOMPLISHMENTS: The model results described above provide a very useful dynamical interpolation between the "compensating subsidence" and "mixing length" regimes. They tie together ideas that were previously thought to be unrelated. This unification opens the door to new predictive tools that are both simpler and more powerful that those in current use. These ideas have already been useful in the scientific planning of ASTEX, a field program projected for 1992.

RESEARCH ACCOMPLISHMENT FOR POSSIBLE USE AT NEPRF: In the past, NEPRF has used several modeling techniques developed wholly or in part by the Principal Investigator. These include a bulk boundary layer parameterization for the Navy's global forecast model, and a radiation parameterization. The present research has led to development of an improved version of the above-mentioned bulk boundary layer parameterization. Improvements include the use of a prognostic turbulence kinetic energy and the introduction of fractional cloudiness. These could be incorporated into the Navy's forecast model.

PAPERS SUBMITTED TO REFEREED JOURNAL, BUT NOT YET PUBLISHED:

NONE

PAPERS PUBLISHED IN REFEREED JOURNALS:

Randall, D. A., 1989: Cloud Parameterization for Climate Models: Status and Prospects. *Atmos. Res.*, **23**, 345-362.

BOOKS OR CHAPTERS SUBMITTED, BUT NOT YET PUBLISHED:

NONE

BOOKS OR CHAPTERS PUBLISHED:

NONE

PRINTED TECHNICAL REPORTS AND NON-REFEREED PAPERS:

Randall, D. A., 1989: Cloudtop Entrainment Instability: Current Knowledge and Key Questions. Paper presented at the *ASTEX Planning Meeting*, July 13-14, 1989, Monterey, California.

Randall, D. A., 1989: A Unified View of Convective Transports by Stratocumulus Clouds, Shallow Cumulus Clouds, and Deep Convection. Paper presented at the *FIRE Science Team Meeting*, July 10-14, 1989, Monterey, California.

Randall, D. A., 1989: Evidence for the Sensitivity of Large-Scale Models to Boundary-Layer Parameterizations. Paper presented at the *Symposium on Boundary-Layer Parameterization and Larger-Scale Models, IAMAP-89*, August 9, 1989, Reading, England.

Randall, D. A. and Q. Shao, 1989: Formulation of a Bulk Boundary Layer Model with partial Mixing and Partial Cloudiness. *Atmospheric Science Report*, Colorado State University (in press).

PATENTS FILED:

NONE

PATENTS GRANTED:

NONE

INVITED PRESENTATIONS AT WORKSHOPS OR PROFESSIONAL SOCIETY MEETINGS:

Randall, D. A., 1989: Evidence for the Sensitivity of Large-Scale Models to Boundary-Layer Parameterizations. Paper presented at the *Symposium on Boundary-Layer Parameterization and Larger-Scale Models, IAMAP-89*, August 9, 1989, Reading, England.

Randall, D. A., 1989: What Should a Boundary-Layer Parameterization for Climate Models Include? Paper presented at the *Workshop on Boundary-Layer Parameterization for Large-Scale Models of the World Climate Research Program*, August 14-15, 1989, Reading, England.

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Randall, D. A., 1989: A Unified View of Convective Transports by Stratocumulus Clouds, Shallow Cumulus Clouds, and Deep Convection. Paper presented at the *FIRE Science Team Meeting*, July 10-14, 1989, Monterey, California.

Randall, D. A., 1989: Cloudtop Entrainment Instability: Current Knowledge and Key Questions. Paper presented at the *ASTEX Planning Meeting*, July 13-14, 1989, Monterey, California.

HONORS/AWARDS/PRIZES FOR GRANT EMPLOYEES:

NONE

TOTAL NUMBER OF GRADUATE STUDENTS AND POST-DOCS SUPPORTED AT LEAST 25% THIS YEAR ON THIS GRANT:

Graduate students	1	Post-docs	0
Graduate student female	1	Post-doc female	0
Graduate student minority	0	Post-doc minority	0
Graduate student Asian	1	Post-doc Asian	0